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JAMES E. KEITH
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Radioactivity Induced in Discoverer 17 by Solar-Flare Protons

JAMES E. KEITH AND ANTHONY L. TURKEVICH

*Enrico Fermi Institute for Nuclear Studies, and
Department of Chemistry, University of Chicago, Chicago, Illinois*

Abstract. A sheet of lead 7 mm thick, part of the recovered United States satellite Discoverer 17, has been examined for evidence of bombardment by solar protons while the satellite was in a polar orbit (November 12–14, 1960) during a class 3^+ solar flare. Bismuth 205 from the reactions $Pb^{206}(p, 2n)Bi^{205}$, $Pb^{207}(p, 3n)Bi^{205}$, and $Pb^{208}(p, 4n)Bi^{205}$ has been isolated by radiochemical techniques from 100-gram quantities of the lead and counted by X-ray gamma coincidence scintillation spectroscopy. The radioactivity at the time of recovery was about 1000 dpm of Bi^{205} per kilogram of lead. Known cross sections for the nuclear reactions involved lead to an integrated omnidirectional flux above 57 Mev of 5.7×10^5 protons/cm². The energy spectrum of the protons is deduced from the variation in depth of the Bi^{205} radioactivity. The exponent in the inverse-power-law differential energy spectrum is between 5 and 6.

Introduction. The examination of cosmic-ray-induced radioactivity in meteorites is now a well-established technique for studying the intensity and constancy of cosmic rays in space and time (see *Arnold* [1961] and *Anders* [1962]). The availability of recovered satellites has recently made possible the investigation of induced radioactivity in such objects as a method of studying the radiation to which they were exposed.

Many of the United States satellites of the Discoverer series placed in polar orbits have been recovered. Discoverer 17 was in orbit during a class 3^+ solar flare. The availability of material from this satellite has permitted investigation by several groups (R. W. Dodson, G. Friedlander, J. Hudis, and O. A. Schaeffer, private communication, 1961; *Stoenner and Davis* [1961]; *Fireman et al.* [1961]; and *Wasson* [1961]). In this paper we describe the radiochemical isolation of Bi^{205} (15.0 d) formed in a sheet of lead from the satellite, and we present a new radiochemical method of determining the energy spectrum of the protons by the variation of the induced radioactivity with depth in the target. From the amount of radioactivity in the lead and from the cross section for its production by protons [*Bell and Skarsgard*, 1956] we have estimated that the integrated flux above 57 Mev to which the satellite was exposed was between 0.74×10^5 and 5.7×10^5 protons/cm², depending on the directionality of the particles. The variation of the radioactivity with depth in the lead is explicable by an energy spectrum varying as $E^{-5.6\pm1.6}$ or $E^{-5.2\pm1.7}$, again depending on the directionality of the flux.

Experimental techniques. Discoverer 17 was placed in a polar orbit at 2042 GMT on November 12, 1960, from Vandenberg Air Force Base, California, and was recovered at 2230 GMT on November 14, 1960, over the Pacific Ocean. The flight lasted 2988 minutes, the perigee was 191 km, the apogee 977 km, and the period 96.4 minutes. Just before the launching of Discoverer 17 solar protons from a class 3^+ solar flare began to reach the earth.

Discoverer 25, orbited during a period of solar quiescence, furnished lead for a background run.

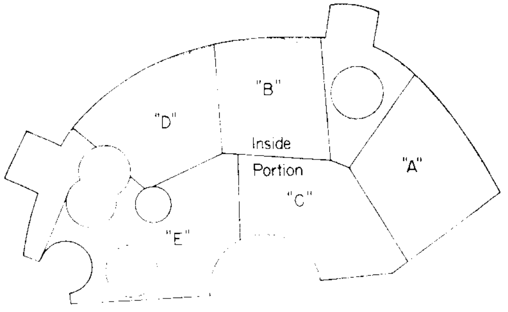

Fig. 1. Diagram of our piece of the lead collar counterweight of Discoverer 17. This diagram shows the piece (roughly half) of the counterweight from which the lead was taken for the radiochemical separations described in this paper. The collar, which had a slight convexity in the plane of the paper, was cut up as marked, and parts *A*, *B*, *C*, *D*, and *E* were used as described herein. The circles in the collar were cut out during its fabrication, before the flight.

Launched into polar orbit from Vandenberg Air Force Base at 2303 GMT on June 16, 1961, it re-entered the atmosphere at 0108 GMT on June 19, 1961. The perigee and apogee of its orbit were 224 and 405 km, respectively.

The lead from Discoverer 17 used in this experiment was in the satellite as a collar-shaped counterweight just under the ablative covering of the nose. The thickness of the ablative covering and the aluminum alloy shell outside the lead varied from 2 to 3 g/cm². The lead collar was divided into areas, and the Bi^{205} was separated from areas *A*, *B*, *C*, and *D* (see Figure 1). Iridium, rhenium, tantalum, and the gross rare earths were separated from area *E*; they will be the subject of a separate paper. Areas *A*, *B*, *C*, and *D* were cleaned of all extraneous material, and successive layers of lead 0.040 inch thick were machined off. A sample of the lead from which the collar was made, but which was not flown, was used for blank runs. The lead from Discoverer 25 was also from a collar, but it was used in these studies without machining into layers.

The lead (100 to 500 grams) was dissolved in the presence of 100 mg of bismuth carrier in dilute nitric acid. (Analysis of the lead showed that it contained 0.01 per cent bismuth impurity. This was included in computing the fraction of bismuth recovered by the chemical operations.) The bismuth was separated from the major portions of the lead by electrodeposition from the acid solution (pH 1) using the cell [Pb, Pb^{++}, Bi^{+++}, Bi(Pt)] with an electrolyte volume of about 4 liters. (This method was adapted from the one described by *ASTM* [1960]). The cell was operated for two successive 8-hour periods to obtain about 90 per cent yields. The bismuth was washed off the electrodes with nitric acid, sulfuric acid was added, and the solution was evaporated to fumes of sulfuric acid. The solution was diluted to 9 *N* and cooled. Any gross amounts of lead that were still present precipitated at this stage and were removed by centrifugation. The acid solution containing the bismuth was then treated with hydrogen sulfide. Under these conditions bismuth sulfide precipitates, lead sulfide does not. The brown-black precipitate was collected by centrifugation and dissolved in a little concentrated hydrochloric acid and as little nitric acid as possible. The hydrochloric acid was destroyed by the addition of excess nitric acid and heating. The solution was diluted, and bismuth oxychloride precipitated [see *Hillebrand et al.*, 1953]. The bismuth oxychloride was dissolved in nitric acid; the chloride ion was destroyed; and bismuth phosphate [*Hillebrand et al.*, 1953] was precipitated, ignited at 800°C, and weighed to determine the chemical yield. The bismuth phosphate was mounted between two aluminum cards for counting.

Chemical separation of bismuth from lead concentrates the Bi^{210} (RaE) daughter of Pb^{210} (RaD) that may be present in the original lead. The RaE was easily detected in our samples by the energetic electrons it emits and by the 5-day half-life displayed by the X rays from the bismuth immediately after separation from the lead. (Radium E shows some apparent X-ray activity in the thick samples of bismuth due to fluorescence effects.) The X-ray gamma coincidence technique used in this study eliminated this source of confusion, since RaE has no significant amount of gamma activity.

The sample was placed between two cylindrical sodium iodide crystals. The smaller of the two (1.5 inches in diameter and 0.5 inch thick) was used to detect the 75-kev lead X ray emitted in the decay of Bi^{205}. A single-channel analyzer, with its window centered on the X-ray energy, analyzed the output of this smaller crystal. The larger crystal (3 inches in diameter and 3 inches thick) detected radiation in coincidence with the X ray. The output of the larger crystal was analyzed by a transistorized 256-channel pulse height analyzer. The 703-kev peak was measured in the analyzer to determine the activity of the Bi^{205}.

Several other samples besides the bismuth samples from Discoverer 17 were measured during the course of this work. The one used routinely for background determinations consisted of two aluminum cards with nothing between them. A sample serving as a blank for radioactivity in the original lead and for the chemical procedure consisted of bismuth separated from 406 grams of the lead from which the counterweight for Discovery 17 was fabricated and which had not been in orbit. Finally, there was the sample of bismuth separated from 194 grams of lead from the counterweight of Discoverer 25.

The activity of the samples from Discoverer 17 and the two other bismuth samples was measured in a series of overnight counts, usually somewhat longer than 1000 minutes. Every second or third overnight count was a routine background. The counters were monitored daily with a Bi^{205} sample produced at the cyclotron and a Na^{22} source. The energy and efficiency calibrations of the apparatus were constant; variations never exceeded 1 per cent.

As far as possible the calibrations and measurements were so performed as to make them comparable to the cross-section measurements of *Bell and Skarsgard* [1956]. The physical constants and decay parameters for Bi^{205} were those used by Bell and Skarsgard. Our 1.5-inch by 0.5-inch crystal was used to detect the X rays and was calibrated by a known activity in the same manner as their 1.5-inch by 1.0-inch crystal. In our work the source of known activity was a standardized solution of Hg^{203} whose 73-kev thallium X ray is a good match for the 75-kev lead X ray of Bi^{205}. The number of disintegrations in the standardized solution of Hg^{203} was determined by 2π beta counting. The Hg^{203} standard consisted of a known amount of this solution evaporated on 100 mg of bismuth phosphate and sandwiched between aluminum cards. The values for the internal conversion coefficient of Hg^{203}, $\alpha_k = 0.163$, given by *Nijgh et al.* [1958–59] and the fluorescence yield, $\omega_k = 0.946$, given by *Burhop* [1955], were used in these calibrations.

The X-ray detection rate in the calibrated 1.5-inch by 0.5-inch crystal was related to that in the 703-kev peak of the 3-inch by 3-inch crystal in coincidence with the X rays by counting the Bi^{205} standard supplied by Pierson. This same standard was used as a daily monitor sample for the coincidence counting set up. The efficiency of detection of the Bi^{205} by this coincidence method was 0.70 per cent.

Experimental results. The backgrounds in the 703 peak coincident with the lead X rays were measured in 24 overnight counts interspersed among the sample counts during January, February, and March 1961. The average value was 12.6 $\pm$ 0.7/1000 minutes. (In this paper all errors are given as plus or minus a standard deviation.) The measurements of the activities from the Discoverer 17 unflown lead and the Discoverer 25 lead were made later, and separate measurments of the background, taken during the appropriate periods, were used for these samples.

The counting rates of samples from Discoverer 17 varied from 45/1000 minute for the most active sample down to a small fraction of the background. The decay of all the samples was consistent with a 15-day half-life, although the data for most of them were not sufficient to establish the half-life.

A typical set of measurements on bismuth from the flown lead of Discoverer 17 is presented in Table 1. It is seen from column 4 of this table that there was a statistically significant excess of activity in the sample at early times. The net counts for each counting period, corrected to midnight February 1, 1961, on the basis of a 15-day half-life (column 5, Table 1), were averaged with appropriate weights (column 6, Table 1) to obtain the best value, $\bar{A}_i$, of the activity on that date. The average corrected activity on February 1, 1961, calculated for all the samples in this way, is reported in Table 2.

Tables 3 and 4 give corresponding data for the Discoverer 17 unflown lead and the lead from Discoverer 25. It is seen that there was no net activity in either sample. Thus the flown lead from Discoverer 17 had very many more times the activity than the lead from Discoverer 25. The chemical separation, the nature of the counting used, and the consistency with a 15-day half-life make it extremely probable that the activity was 15-day Bi^{205}. The presence of the activity in the lead from Discoverer 17 but not in the lead

TABLE 1. Counting Data for Typical Sample of Bismuth from the Flown Lead of Discoverer 17*

Mean Time of Count	Time, min	Gross Count in 703 Peak, (1000 min)$^{-1}$	Net Count, (1000 min)$^{-1}$	A_i, Net Count Corrected to Midnight 2/1/61	w_i Stat. Weight
Midnight 1/28/61	1030	45.6	33.0 ± 6.7	27.4	0.896
Midnight 1/30/61	920	50.0	37.4 ± 7.4	34.1	0.753
Midnight 2/27/61	1050	21.9	9.3 ± 4.6	30.9	0.134
Midnight 3/2/61	1260	20.7	8.1 ± 4.1	30.9	0.125
Midnight 3/17/61	1250	19.2	6.6 ± 4.0	50.5	0.056

* First 0.040-inch layer, area *BCD* of Figure 1.

from Discoverer 25 strongly suggests that the activity was caused by particles connected with the solar flare of November 12, 1960.

Although it is true that Discoverer 17 grazed the inner side of the Van Allen belt during orbits in which apogee lay between 210° and 30° east longitude, it is fairly easy to show that the belt did not contribute significantly to the total number of protons that impinged upon the satellite. From the information compiled by *Dessler* [1961] the fraction of protons due to the belt can be estimated as about 1 per cent. However, more recent estimates have been made. Fireman, Tilles et al. (private communication, 1962) have integrated to total number of protons above 31 Mev due to the belt experienced by various satellites in their entire flights. Using their value for Discoverer 17 (2.3×10^7 protons/cm^2), and the differential spectrums published by *Naugle and Kniffen* [1962], to obtain the fraction of protons having energies above 57 Mev, we find that the fraction due to the belt lies between 0.8 and 2 per cent, depending on which spectrum is chosen. Of course, the belt is thought to vary slowly in intensity at most locations by a factor of 2 or 3. In any event these contributions would be negligible.

In Table 2, two results for the first 0.040-inch layer of lead are reported: one for area *A* and one for the remaining areas *B*, *C*, and *D*. The difference in activities reported there has been carefully verified. It is thought that the difference is due either to a directional component in the flux or to the orientation of part *A* toward the local zenith of the satellite. (Discoverer 17 did not rotate on its axis; it maintained the same orientation toward the earth throughout its orbit.) It is unfortunate that limitations in time for chemical separations and counting did not permit a further examination of this aspect of the problem. The two results were combined, weighted by the areas represented, to give a point comparable to the others in Table 2.

The last two columns of Table 2 indicate, although the errors are rather large, that the Bi^{205} in the lead was produced somewhat more abundantly at the surface than in the interior. This depth dependence can be used to estimate the energy spectrum of the particles producing the radioactivity.

TABLE 2. Samples of Bi^{205} from Discoverer 17

Sample	$\bar{A}$ (1000 min)$^{-1}$ Average Activity on 2/1/62	Equivalent Weight of Lead,* grams	$\bar{A}$/kg Pb/1000 min at Midnight 2/1/61	D^0, dpm/kg Pb, at Time of Recovery
0–0.04 in. (*A*)	19.1 ± 2.1	47		
0–0.04 in. (*BCD*)	31.1 ± 4.0	120	282 ± 24.5†	1480 ± 129
0–04–0.08 in. (*ABCD*)	38.2 ± 5.5	190	202 ± 30.6	1050 ± 160
0.08–0.12 in. (*ABCD*)	46 ± 11.6	316	145 ± 46.7	758 ± 192

* Equivalent weight of lead is the product of the chemical yield and the weight of the sample of lead used.
† Sections *A* and *BCD* of the first layer were done separately and were combined, weighting by the areas involved, to give a value comparable to the deeper layers, which were over areas *A*, *B*, *C*, and *D*.

TABLE 3. Unflown Lead from Discoverer 17 Lead

Mean Time of Count	Time of Count, min	Gross Count in 703 Peak, $(1000 \text{ min})^{-1}$
Midnight 3/13/61	1260	11.9
Midnight 3/15/61	1300	11.5
Midnight 3/17/61	1020	18.6
Midnight 5/6/61	1170	15.4
Midnight 5/8/61	770	19.6
Midnight 5/11/61	1330	14.3
		(14.0 ± 1.44)/1000 min

Background during this period = (13.6 ± 2.04)/1000 min.

Net activity in the 703 peak = (0.40 ± 2.50)/1000 min.

By integration of the specific activity as a function of depth on the assumption of exponential behavior (see the next section) we find the average value of the Bi^{205} activity in the lead of Discoverer 17 for our particular section to be 679 ± 85 dpm per kilogram of lead at the time of recovery. This is to be compared with the value reported by Dodson et al. for their section, 550 ± 300 dpm per kilogram, for the same radioactivity in the lead of the same satellite. They used a different method of counting. The results are in satisfactory agreement.

Interpretation and discussion. We interpret the production of Bi^{205} in the lead of Discoverer 17 as due to the reaction of $Pb(p, xn)Bi^{205}$. The cross section for the production of Bi^{205} from the separate lead isotopes have been measured by *Bell and Skarsgard* [1956]. The production cross section from natural lead, calculated from their numbers, is shown in Figure 2. These data have been made to join smoothly to the 380-Mev cross section for $Bi^{209}(p, 4n)Po^{206}$ reaction [*Miller and Hunter*, 1959] to provide an estimate of the high-energy tail. It is seen that the cross section is very small below 20 Mev and tapers off above 60 Mev.

If we assume that the differential spectrum of particles associated with the solar flare can be represented in the usual form, $I = kE^{-n}$, and make certain other assumptions about the nature of the proton flux and its absorption while passing through materials, it is possible to estimate both the total intensity and the exponent n. We have done this by finding values for k and n such that the absorption curve (activity versus depth in the lead) is reproduced by a plot of $\int_0^\infty I_x(T)\sigma(T)\, dT$ versus depth in the lead. (Throughout this paper, E will denote the kinetic energy of protons in space, and T will denote their energy in an absorber, such as lead.) In this integral, $I_x(T)$ is the intensity of the protons as a function of their energy in the lead at a depth x, and $\sigma(T)$ is the excitation function for the production of Bi^{205} from natural lead by protons.

We take as our models two extreme cases: (*a*) that the flux in space is perpendicular to the lead surface, and (*b*) that the flux is omnidirectional.

The intensity in the lead $I_x(T)$, after passing through shielding material, represented in the models by 3 g/cm² of aluminum, is obtained by fitting the data on the stopping power of aluminum and lead given by *Sternheimer* [1959] with the expression $-dE/dx = CE^{-a}$. In the energy range 30–300 Mev a good fit is obtained by

TABLE 4. Discoverer 25 Lead

Mean Time of Count	Time of Count, min	Gross Count in 703 Peak
Midnight 7/4/61	1220	20
Midnight 7/6/61	1250	13
Midnight 7/8/61	1193	23
Midnight 7/10/61	1714	22
Midnight 7/12/61	1050	16
Midnight 7/14/61	1106	14
Midnight 7/16/61	1172	20
		(14.7 ± 1.3)/1000 min

Background during this period = (16.0 ± 1.3)/1000 min.

Net activity in 703 peak = (−1.3 ± 1.8)/1000 min.

Net activity in 703 peak at time of recovery = (−11.4 ± 16.1)/1000 min.

Disintegration rate at time or recovery = (−10.4 ± 14.6) dpm/kg Pb.

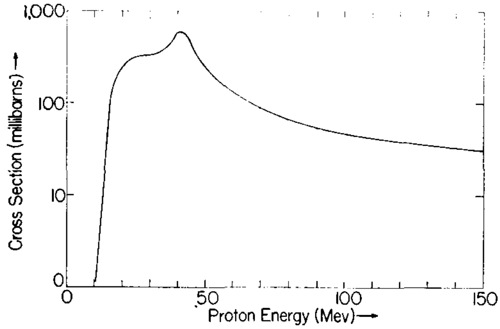

Fig. 2. Excitation function for the production of Bi^{205} by protons on natural lead. This excitation function is the sum of the excitation functions of the individual isotopes of lead as measured by *Bell and Skarsgard* [1956] weighted according to the abundances of these isotopes in natural lead.

allowing a to equal 0.74 for aluminum and 0.65 for lead. A considerable simplification in calculations at little cost in accuracy is obtained by taking $a = 0.7$ for both lead and aluminum. Then, imposing the condition for conservation of protons, we obtain an expression for the intensity in the lead as a function of energy. Figure 3 shows the energy spectrum for the case $n = 4.4$ and perpendicular flux, in space and in the lead. The curves in the case of the omnidirectional flux are very similar but depressed further from the curve representing the flux in space. It should be noted that, in both cases, the intensities in the lead approach the intensity in free space as the proton energy increases, as one would expect.

The integrals

$$\int_0^\infty I_x(T)\sigma(T)\ dT$$

and

$$\int_0^\infty \int_0^{\pi/2} J(T,\ \theta)\sigma(T)\ d\theta\ dT$$

have been evaluated numerically for four depths in the lead for n = 1, 2.7, 4.4, 6.1, and 7.8. The results for the perpendicular case are presented in Figure 4. Inspection of the figure shows that the best match in slopes with the experimental data lies between $n = 4.4$ and $n = 6.1$ for both assumptions about the directionality of the flux. A quantitative estimate of the best match can be made as follows: Let $\int_0^\infty I_x\sigma\ dT$ as a function of the thickness of the lead be represented by $\log \int_0^\infty I_x\sigma\ dT = a + bx$, where x is the thickness and a and b are constants, found by the least-squares method, for each value of n. Then, if the experimental points are fitted to the function $\log D^0 = a + bx$ by the least-squares method, taking into account the uncertainties in the experimental points, a value of the slope b and its standard deviation can be found. The constant a and its standard deviation can also be found; they are directly related to the value of the disintegration rate of Bi^{205} at the surface of the lead, D_0^0, and its standard deviation. The slope b and its standard deviation, in terms of n, are found in Table 5 for both the perpendicular and the omnidirectional case.

To obtain the total flux above 57 Mev (the least energy of protons in space that can produce the nuclear reaction after going through the

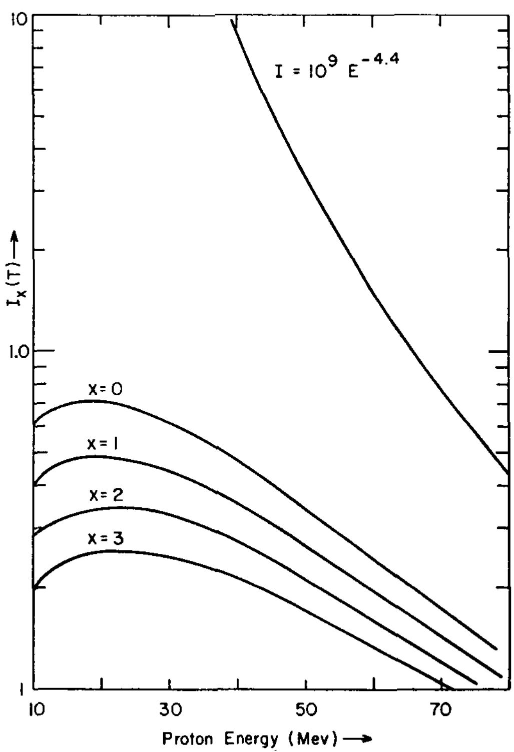

Fig. 3. The proton spectrum in space and in lead for the case $n = 4.4$ and a perpendicular flux. The differential energy spectrums appearing above are those for a flux of protons having a differential energy dependence $E^{-4.4}$, in space, and the same flux after passing through 3 g/cm^3 of aluminum ($x = 0$) and 0.04, 0.08, and 0.12 inch of lead (x = 1, 2, and 3), respectively.

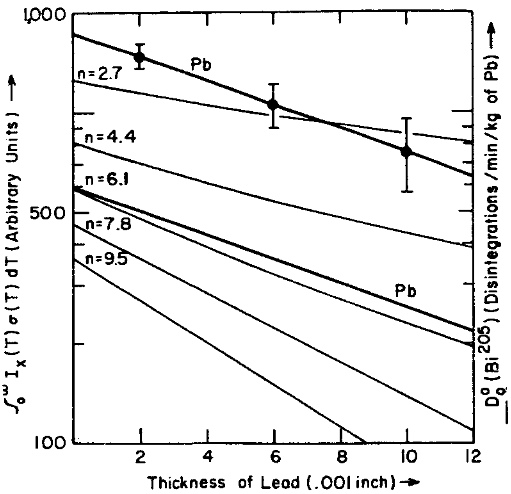

Fig. 4. Plot of $\int_0^\infty I_x(T)\sigma(T)\,dT$ and the disintegration rate of Bi^{205} at the time of recovery versus thickness of the lead. The heavy line with the errors indicated represents the experimentally determined disintegration rate of Bi^{205} per minute per kilogram of lead as a function of the thickness of the lead. The lower heavy line parallel to it is drawn to facilitate comparison of the experimental slope with the slopes of the lines marked $n = 4.4$ and $n = 6.1$. The thin lines represent $\int_0^\infty I_x(T)\sigma(T)\,dT$ as a function of the thickness of the lead for the values of n indicated and a perpendicular flux. The corresponding integrals for the omnidirectional case have slopes very similar to those of their perpendicular counterparts.

shielding material) we find $\int_{57}^\infty I(E)\,dE$. The integrated flux above 57 Mev for the case $n = 5.23$ is 7.4×10^7 protons/cm² assuming a perpendicular flux, and 5.7×10^8 protons/cm² assuming an omnidirectional flux. The integrated flux is a function of n. If n is increased by 1, the integrated flux is decreased by a factor of about 12 to 14, depending on the directionality of the flux; if n is decreased by 1, the integrated flux is increased by about the same factor. Thus the uncertainty in the directionality of the flux, and in n, greatly overshadows the counting errors in the estimation of the integrated flux.

Table 5 compares our results on the characteristics of the proton flux with those of other authors. Dodson et al. estimate an n value of 5 from comparison of the production of Bi^{205} from the lead and of Ar^{37} from the stainless steel of Discoverer 17 [*Stoenner and Davis,* 1961].

Wasson [1961] measured the gross gamma activity in an emulsion block carried by Discoverer 17. In interpreting his data he assumed that the activity was due to the reaction $Ag^{107}(p, pn)Ag^{106}$, that the excitation function for this reaction was a constant, 100 mb, between 45 Mev and 400 Mev, and that the incident flux was omnidirectional. In view of his assumption of a constant excitation function, any energy spectrum for the incident flux is permissible, and it is not clear what spectrum he assumed to convert from flux in the emulsion to flux in space. In view of these differing assumptions it is not clear whether the integrated flux above 45 Mev that Wasson gets (6.6×10^8/cm²) is to be considered in agreement with our value 5.7×10^8/cm².

On the other hand *Van Allen* [1961] gives a value of 2×10^9/cm² above 30 Mev, obtained with counters on the satellite Explorer 7. However, since the data of Explorer 7 were taken at a geomagnetic latitude of 58°, it may be that Discoverer 17, on its polar orbit, actually saw a higher flux. The value of $n \geq 3.4$ derived by

TABLE 5. Summary of Results on the Integrated Proton Flux Due to Solar Flare of November 12, 1960

Investigators	Method	n	$\int_{57}^\infty I(E)\,dE$, cm⁻²	
Keith and Turkevich	Bi^{205} vs. Depth	5.6 ± 1.6	$(7.4 \pm 0.84) \times 10^7$	(*a*)*
		5.2 ± 1.7	$(5.7 \pm 0.64) \times 10^8$	(*b*)*
Dodson, Friedlander, Hudis, and Schaeffer	Bi^{205}/Ar^{37}	5	$(5.5 \pm 3) \times 10^7$	(*a*)
Wasson	Ag^{106}	0	6.6×10^8	(*b*)
Van Allen	Explorer 7 counters	≥3.4	1.3×10^8	(*b*)†

(*a*) Perpendicular flux.
(*b*) Omnidirectional flux.
* The standard deviations listed for $\int_{57}^\infty I(E)\,dE$ involve only errors in counting, not in n.
† A derived value obtained for purposes of comparison by applying the assumption that I varies as $E^{-5.2}$ to the integral flux value of 2×10^9 above 30 Mev reported by this investigator.

comparison of these Explorer 7 data with terrestrial counter measurements would appear not necessarily to be comparable with our values obtained from measurements at a different locus.

We therefore conclude that our measurements are in moderate agreement with those of other workers. Discoverer 17 was subjected to an integrated flux of protons above 57 Mev of at least 7.4×10^7 protons/cm^2. This flux was even higher if any part of it was at an angle other than perpendicular to the lead, and it was 5.7×10^8 protons/cm^2 if the flux was omnidirectional over the upper hemisphere. It is to be noted that this flux is simply the total number of protons per square centimeter incident upon the satellite in the two days in orbit. No correction for geomagnetic shielding has been made. The energy spectrum of the protons was much steeper than that of ordinary cosmic rays; a power law of the type E^{-n} with n between 5 and 6 explains our results.

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